

7.3 TECHNOLOGY SUMMARY PROFILES

This section of the CTSA presents summary profiles of each of the MHC technologies. The profiles summarize key information from various sections of the CTSA, including the following:

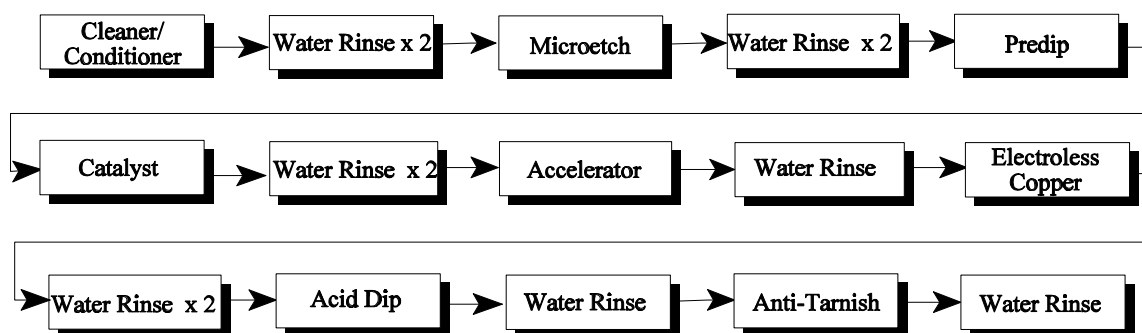
- Generic process steps, typical bath sequences and equipment configurations evaluated in the CTSA.
- Human health and environmental hazards data and risk concerns for non-proprietary chemicals.
- Production costs and resource (water and energy) consumption data.
- Federal environmental regulations affecting chemicals in each of the technologies.
- The conclusions of the social benefits/costs assessment.

The first summary profile (Section 7.3.1) presents data for both the baseline process and the conveyorized electroless copper process. Sections 7.3.2 through 7.3.7 present data for the carbon, conductive polymer, graphite, non-formaldehyde electroless copper, organic-palladium, and tin-palladium technologies, respectively.

As discussed in Section 7.2, each of the alternatives appear to provide private as well as external benefits compared to the non-conveyorized electroless copper process (the baseline process), though net benefits could not be assessed without a more thorough assessment of effects on jobs and wages. However, the actual decision of whether or not to implement an alternative occurs outside of the CTSA process. Individual decision-makers may consider a number of additional factors, such as their individual business circumstances and community characteristics, together with the information presented in this CTSA.

7.3.1 Electroless Copper Technology

Generic Process Steps and Typical Bath Sequence



Equipment Configurations Evaluated: Non-conveyorized (the baseline process) and conveyorized.

Risk Characterization

Table 7.18 summarizes human and environmental hazards and risk concerns for non-proprietary chemicals in the electroless copper technology. The risk characterization identified occupational inhalation risk concerns for ten chemicals in non-conveyorized electroless copper processes and dermal risk concerns for eight chemicals for either equipment configuration. No public health risk concerns were identified for the pathways evaluated, although formaldehyde cancer risks as high as 1×10^{-7} and 3×10^{-7} were estimated for non-conveyorized and conveyorized electroless copper processes, respectively.

Table 7.18 Summary of Human Health and Environmental Hazard Data and Risk Concerns for the Electroless Copper Technology

Chemical ^a	Human Health Hazard and Occupational Risks ^b				Carcinogenicity Weight-of-Evidence Classification	Aquatic Toxicity CC (mg/l)
	Inhalation ^c		Dermal ^d			
	Toxicity ^c (mg/m ³)	Risk Concerns	Toxicity ^e (mg/kg-d)	Risk Concerns		
Alkene Diol	NR ^f	no	NR	no	Probable human carcinogen ^g	NR
Alkyl Oxide	NR ^f	no	NR	no	Possible/probable human carcinogen ^g	NR
Ammonium Chloride	ND	NA	1691(NOAEI)	no	none	0.05
Benzotriazole	ND	NE	109 (LOAEL)	no	none	0.023 ^h
Boric Acid	ND	NE	62.5 (LOAEL)	no	none	0.022
Copper (I) Chloride ⁱ	0.6 (LOAEL)	yes	0.07 (LOAEL)	yes	EPA Class D	0.0004
Copper Sulfate ⁱ	ND	NE	ND	NE	none	0.00002
Cyclic Ether	ND	NA	NR	yes	none	NR
Dimethylaminoborane	ND	NE	ND	NE	none	0.007 ^j
Dimethylformamide	0.03 (RfC)	no	125 (LOAEL)	no	IARC Group 2B ^k	0.12
Ethanolamine	12.7 (LOAEL)	yes	320 (NOAEL)	no	none	0.075
2-Ethoxyethanol	0.2 (RfC)	yes	0.4 (RfD)	no	none	5.0
Ethylenediaminetetraacetic Acid (EDTA)	ND	NA	ND	NE	none	0.41
Ethylene Glycol	31	yes	2 (RfD)	no	none	3.3
Fluoroboric Acid	ND	NE	0.77	yes	none	0.125
Formaldehyde	0.1 ppm (LOAEL)	yes	0.2 (RfD)	yes	EPA Class B1 IARC Group 2A	0.0067
Formic Acid	59.2 (NOAEL)	yes	ND	NE	none	0.08
Hydrochloric Acid ^l	0.007 (RfC)	no	ND	NE ^m	IARC Group 3	0.1
Hydrogen Peroxide	79	no	630 (NOAEL)	no	IARC Group 3	1.2
Hydroxyacetic Acid	ND	NE	250 (NOAEL)	no	none	1 ⁿ

Chemical ^a	Human Health Hazard and Occupational Risks ^b				Carcinogenicity Weight-of-Evidence Classification	Aquatic Toxicity CC (mg/l)
	Inhalation ^c		Dermal ^d			
	Toxicity ^c (mg/m ³)	Risk Concerns	Toxicity ^e (mg/kg-d)	Risk Concerns		
Isopropyl Alcohol; or 2-Propanol	980 (NOAEL)	no	100 (NOAEL)	no	none	9.0
m-Nitrobenzene Sulfonic Acid	ND	NE	ND	NE	none	5.0
Magnesium Carbonate	Generally regarded as safe (U.S. FDA as cited in HSDB, 1995)				none	1.0 ^j
Methanol	1,596 - 10,640	yes	0.5 (RfD)	no	none	17
Nitrogen Heterocycle	ND	NA	NR	yes	none	NR
Palladium	ND	NA	0.95 (LOAEL)	yes	none	0.00014
Peroxymonosulfuric Acid	ND	NA	ND	NE	none	0.030 ^j
Potassium Bisulfate	ND	NE	ND	NE	none	>1.0 ^j
Potassium Cyanide	ND	NE	0.05 (RfD)	no	none	0.79
Potassium Hydroxide	7.1	no	ND	NE	none	0.08
Potassium Persulfate	ND	NE	ND	NE	none	0.92
Potassium Sodium Tartrate	Generally regarded as safe (U.S. FDA as cited in HSDB, 1996)				none	ND
Potassium Sulfate	15 (TC _{Lo})	no	ND	NE	none	0.11
Sodium Bisulfate	ND	NA	ND	NE	none	0.058
Sodium Carbonate	10 (NOAEL)	no	ND	NE	none	2.4
Sodium Carboxylate	ND	NA	NR	yes	none	NR
Sodium Chlorite	ND	NA	10 (NOAEL)	yes	none	0.00016
Sodium Cyanide	ND	NE	0.04 (RfD)	no	none	0.79
Sodium Hydroxide	2 (LOAEL)	yes	ND	NE	none	2.5
Sodium Hypophosphite	ND	NA	ND	NE	none	0.006 ^j
Sodium Sulfate	ND	NA	420 (NOAEL)	no	none	0.81
Stannous Chloride	ND	NA	0.62 (RfD)	yes	none	0.0009
Sulfuric Acid	0.066 (NOAEL)	yes	ND	NE ^m	none	2.0
Tartaric Acid	ND	NE	8.7	no	none	1.0
Tin Salt	ND	NA	NR	no	none	NR
p-Toluene Sulfonic Acid	ND	NA	ND	ND	none	1.0 ^j
Triethanolamine	ND	NA	32 (LOAEL)	no	none	0.18

^a Chemicals in bold were in all electroless copper technologies evaluated, unless otherwise noted.

^b Risk concerns are for MHC line operators (the most exposed individual).

^c Inhalation risk concerns for non-conveyorized process only. Inhalation risk from fully enclosed, conveyorized process is assumed to be negligible.

^d Dermal risk concerns apply to both conveyorized and non-conveyorized equipment.

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^e Toxicity measure is RfC, RfD, NOAEL, or LOAEL as indicated. If not indicated, the type of toxicity measure was not specified in the available information, but assumed to be LOAEL in risk calculations.

^f Toxicity data are available but not reported in order to protect proprietary chemical identities.

^g Specific EPA and/or IARC groups not reported in order to protect proprietary chemical identities.

^h Estimated using ECOSAR computer software, based on structure-activity relationship.

ⁱ Either copper (I) chloride or copper sulfate was in all electroless copper lines evaluated.

^j Estimated by EPA's Structure-Activity Team.

^k Cancer risk was not evaluated because no slope (unit risk) factor is available.

^l Hydrochloric acid was listed on the MSDSs for five of six electroless copper lines.

^m Chronic dermal toxicity data are not typically developed for strong acids.

ND: No Data. No toxicity measure available for this pathway.

NE: Not Evaluated; due to lack of toxicity measure.

NA: Not Applicable. Inhalation exposure level was not calculated because the chemical is not volatile (vapor pressure below 1×10^{-3} torr) and is not used in any air-sparged bath.

NR: Not Reported.

Performance

The performance of the electroless copper technology was demonstrated at seven test facilities, including six sites using non-conveyorized equipment and one site using conveyorized equipment. Performance test results were not differentiated by the type of equipment configuration used. The Performance Demonstration determined that each of the alternative technologies has the capability of achieving comparable levels of performance to electroless copper.

Production Costs and Resource Consumption

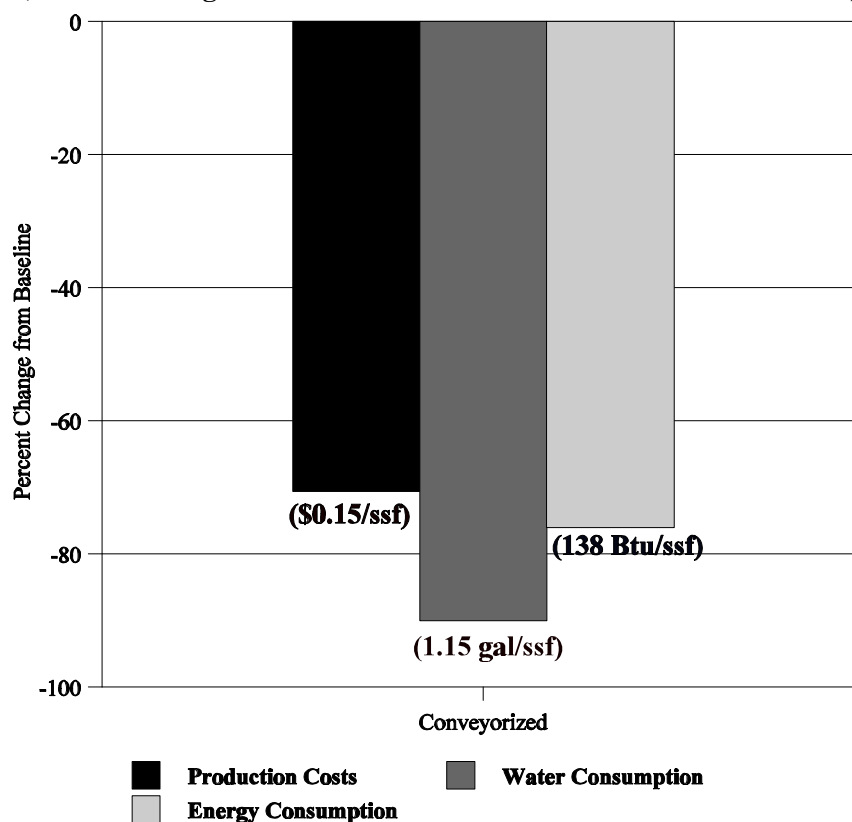
Computer simulation was used to model key operating parameters, including the time required to process a job consisting of 350,000 ssf and the amount of resources (water and energy) consumed. This information was used with a hybrid cost model of traditional cost (i.e., capital costs, etc.) and activity-based costs to determine average manufacturing costs per ssf and water and energy consumption per ssf. Average manufacturing costs for the baseline process (the non-conveyorized electroless copper process) were \$0.51/ssf, while water and energy consumption were 11.7 gal/ssf and 573 Btu/ssf, respectively. However, the conveyorized electroless copper process consumed less water and energy and was more cost-effective than the baseline process (non-conveyorized electroless copper). Figure 7.1 lists the results of the production costs and resource consumption analyses for the conveyorized electroless copper process and illustrates the percent changes in costs and resource consumption from the baseline. Manufacturing costs, water consumption, and energy consumption are less than the baseline by 71 percent, 90 percent, and 76 percent, respectively.

Regulatory Concerns

Chemicals contained in the electroless copper technology are regulated by the Clean Water Act, the Safe Drinking Water Act, the Clean Air Act, the Superfund Amendments and Reauthorization Act, the Emergency Planning and Community Right-to-Know Act, and the Toxic Substances Control Act. In addition, the technology generates wastes listed as hazardous (P or U wastes) under RCRA.

Figure 7.1 Production Costs and Resource Consumption of Conveyorized Electroless Copper Technology

(Percent Change from Baseline with Actual Values in Parentheses)

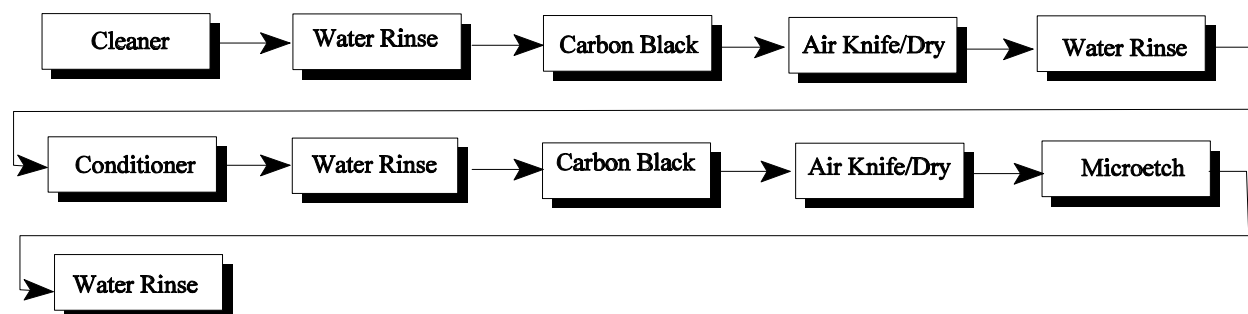


Social Benefits and Costs

A qualitative assessment of the private and external (e.g., social) benefits and costs of the baseline and alternative technologies was performed to determine if there would be net benefits to society if PWB manufacturers switched to alternative technologies from the baseline. It was concluded that all of the alternatives, including the conveyorized electroless copper process, appear to have net societal benefits, though net benefits could not be completely assessed without a more thorough assessment of effects on jobs and wages. For the conveyorized electroless copper process this is due to reduced occupational inhalation risk as well as to lower production costs and to reduced consumption of limited resources (water and energy).

7.3.2 Carbon Technology

Generic Process Steps and Typical Bath Sequence



Equipment Configurations Evaluated: Conveyorized.

Risk Characterization

Table 7.19 summarizes human and environmental hazards and risk concerns for non-proprietary chemicals in the carbon technology. The risk characterization identified no human health risk concerns for the pathways evaluated. However, proprietary chemicals are not included in this assessment and toxicity data were not available for some chemicals in carbon technology baths.

Performance

The performance of the carbon technology was demonstrated at two test facilities. The Performance Demonstration determined that this technology has the capability of achieving comparable levels of performance to electroless copper.

Production Costs and Resource Consumption

Computer simulation was used to model key operating parameters, including the time required to process a job consisting of 350,000 ssf and the amount of resource (water and energy) consumed. This information was used with a hybrid cost model of traditional costs (i.e., capital costs, etc.) and activity-based costs to determine average manufacturing costs per ssf and water and energy consumption per ssf. The conveyorized carbon technology consumed less water and energy and was more cost-effective than the baseline process (non-conveyorized electroless copper). Figure 7.2 lists the results of these analyses and illustrates the percent changes in costs and resources consumption from the baseline. Manufacturing costs, water consumption, and energy consumption are less than the baseline by 65 percent, 89 percent, and 9.6 percent, respectively.

Table 7.19 Summary of Human Health and Environmental Hazard Data and Risk Concerns for the Carbon Technology

Chemical ^a	Human Health Hazard and Occupational Risks ^b			Carcinogenicity Weight-of-Evidence Classification	Aquatic Toxicity CC (mg/l)
	Inhalation ^c	Dermal			
	Toxicity ^d (mg/m ³)	Toxicity ^d (mg/kg-d)	Risk Concerns		
Carbon Black	7.2 (LOAEL)	ND	NE	IARC 2B	ND
Copper Sulfate	ND	ND	NE	none	0.00002
Ethanolamine	12.7 (LOAEL)	320 (NOAEL)	no	none	0.075
Ethylene Glycol	31	2 (RfD)	no	none	3.3
Potassium Carbonate	ND	ND	NE ^e	none	>3.0
Potassium Hydroxide	7.1	ND	NE	none	0.08
Sodium Persulfate	ND	ND	NE	none	0.065
Sulfuric Acid	0.066 (NOAEL)	ND	NE ^f	none	2.0

^a Only one carbon technology was evaluated. All chemicals listed were present in that product line.

^b Risk evaluated for conveyORIZED process only. Risk concerns are for line operator (the most exposed individual).

^c Exposure and risk not calculated. Inhalation exposure and risk from fully enclosed, conveyORIZED process is assumed to be negligible.

^d Toxicity measure is RfC, RfD, NOAEL, or LOAEL, as indicated. If not indicated, the type of toxicity measure was not specified in the available information, but assumed to be a LOAEL in risk calculations.

^e Chemical has very low skin absorption (based on EPA's Structure-Activity Team evaluation); risk from dermal exposure not expected to be of concern.

^f Chronic dermal toxicity data are not typically developed for strong acids.

ND: No Data. No toxicity measure available for this pathway.

NE: Not Evaluated; due to lack of toxicity measure.

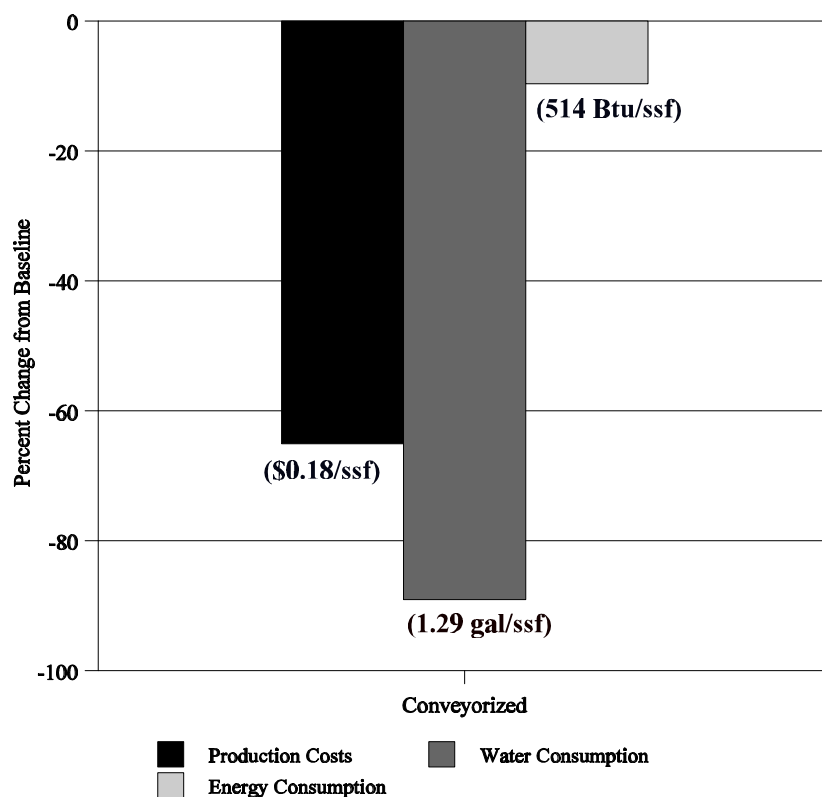
Regulatory Concerns

Chemicals contained in the carbon technology are regulated by the Clean Water Act, the Safe Drinking Water Act, the Clean Air Act, the Superfund Amendments and Reauthorization Act, and the Emergency Planning and Community Right-to-Know Act. The technology does not generate wastes listed as hazardous (P or U waste) under RCRA, but some wastes may have RCRA hazardous characteristics.

Social Benefits and Costs

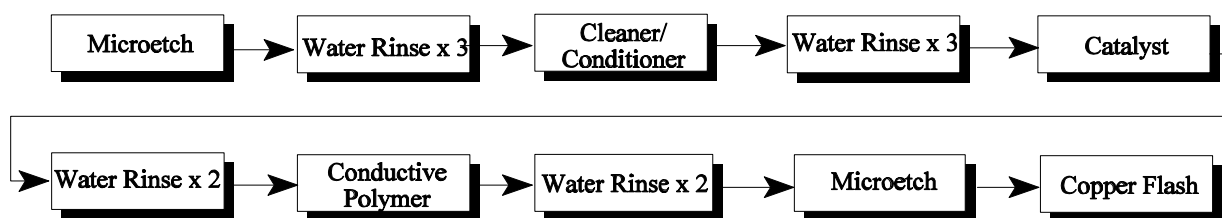
A qualitative assessment of the private and external benefits and costs of this technology suggests there would be net benefits to society if PWB manufacturers switched to the carbon technology from the baseline. Among other factors, this is due to lower occupational risks to workers and to reduced consumption of limited resources (water and, to a lesser degree, energy).

Figure 7.2 Production Costs and Resource Consumption of Carbon Technology
(Percent Change from Baseline with Actual Values in Parentheses)



7.3.3 Conductive Polymer Technology

Generic Process Steps and Typical Bath Sequence



Equipment Configurations Evaluated: Conveyorized.

Risk Characterization

Table 7.20 summarizes human and environmental hazards and risk concerns for non-proprietary chemicals in the conductive polymer technology. The risk characterization identified no human health risk concerns for the pathways evaluated. However, proprietary chemicals are not included in this assessment and no toxicity data are available for some chemicals in conductive polymer technology baths.

Table 7.20 Summary of Human Health and Environmental Hazard Data and Risk Concerns for the Conductive Polymer Technology

Chemical ^a	Human Health Hazard and Occupational Risks ^b			Carcinogenicity Weight-of-Evidence Classification	Aquatic Toxicity CC (mg/l)
	Inhalation ^e	Dermal			
	Toxocity ^d (mg/m ³)	Toxicity ^d (mg/kg-d)	Risk Concerns		
1H-Pyrrole	ND	ND	NE	none	0.21
Peroxymonosulfuric Acid	ND	ND ^e	ND	none	0.030
Phosphoric Acid	ND	ND	NE ^f	none	0.138
Sodium Carbonate	10 (NOAEL)	ND	NE	none	2.4
Sodium Hydroxide	2 (LOAEL)	ND	NE	none	2.5
Sulfuric Acid	0.066 (NOAEL)	ND	NE ^f	none	2.0

^a Only one conductive polymer technology was evaluated. All chemicals were present in that product line.

^b Risk evaluated for conveyorized process only. Risk concerns are for line operator (the most exposed individual).

^c Exposure and risk not calculated. Inhalation exposure and risk from fully enclosed, conveyorized process is assumed to be negligible.

^d Toxicity measure is RfC, RfD, NOAEL, or LOAEL, as indicated. If not indicated, the type of toxicity measure was not specified in the available information, but assumed to be a LOAEL in risk calculations.

^e Chemical has very low skin absorption (based on EPA's Structure-Activity Team evaluation); risk from dermal exposure not expected to be of concern.

^f Chronic dermal toxicity data are not typically developed for strong acids.

ND: No Data. No toxicity measure available for this pathway.

NE: Not Evaluated; due to lack of toxicity measure.

Performance

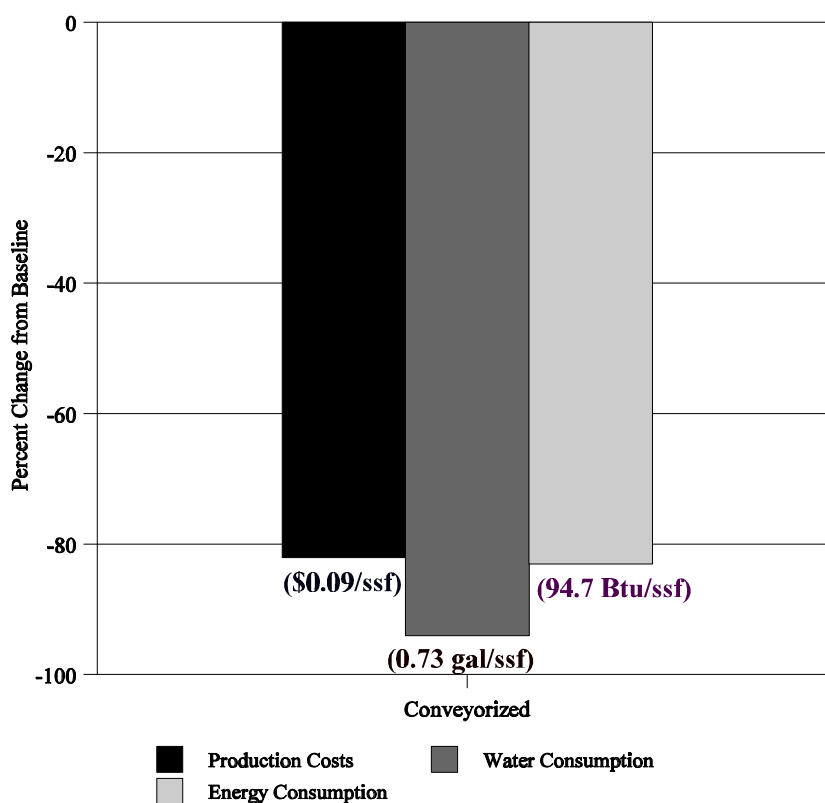
The performance of the conductive polymer technology was demonstrated at one test facility. The Performance Demonstration determined that this technology has the capability of achieving comparable levels of performance to electroless copper.

Production Costs and Resource Consumption

Computer simulation was used to model key operating parameters, including the time required to process a job consisting of 350,000 ssf and the amount of resources (water and energy) consumed. This information was used with a hybrid cost model of traditional costs (i.e., capital costs, etc.) and activity-based costs to determine average manufacturing costs per ssf and water and energy consumption per ssf.

The conveyorized conductive polymer technology consumed less water and energy than the baseline process (non-conveyorized electroless copper). Figure 7.3 lists the results of these analyses and illustrates the percent changes in resources consumption from the baseline. Manufacturing costs, water consumption, and energy consumption are less than the baseline by 82 percent, 94 percent, and 83 percent, respectively.

Figure 7.3 Production Costs and Resource Consumption of Conductive Polymer Technology
(Percent Change from Baseline with Actual Values in Parentheses)



Regulatory Concerns

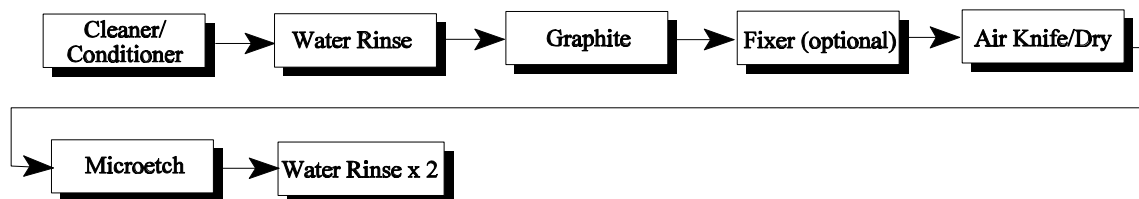
Chemicals contained in the conductive polymer technology are regulated by the Clean Water Act, the Clean Air Act, and the Emergency Planning and Community Right-to-Know Act. The technology does not generate wastes listed as hazardous (P or U waste) under RCRA, but some wastes may have RCRA hazardous characteristics.

Social Benefits and Costs

A qualitative assessment of the private and external benefits and costs of this technology suggests there would be net benefits to society if PWB manufacturers switched to the conductive polymer technology from the baseline. Among other factors, this is due to lower occupational risks to workers and to reduced consumption of limited resources (water and energy).

7.3.4 Graphite Technology

Generic Process Steps and Typical Bath Sequence



Equipment Configurations Evaluated: Conveyorized.

Risk Characterization

Table 7.21 summarizes human and environmental hazards and risk concerns for chemicals in the graphite technology. The risk characterization identified no human health risk concerns for the pathways evaluated. However, the identification of proprietary chemicals was only provided by one of the two companies that submitted information concerning the graphite process. In addition, toxicity data was not available from some chemicals in the graphite technology baths.

Performance

The performance of the graphite technology was demonstrated at three test facilities. The Performance Demonstration determined that this technology has the capability of achieving comparable levels of performance to electroless copper.

Production Costs and Resource Consumption

Computer simulation was used to model key operating parameters, including the time required to process a job consisting of 350,000 ssf and the amount of resources (water and energy) consumed. This information was used with a hybrid cost model of traditional costs (i.e., capital costs, etc.) and activity-based costs to determine average manufacturing costs per ssf and water and energy consumption per ssf. The conveyorized graphite technology consumed less water and energy and was more cost-effective than the baseline process (non-conveyorized electroless copper). Figure 7.4 lists the results of these analyses and illustrates the percent changes in costs and resource consumption from the baseline. Manufacturing costs, water consumption, and energy consumption are less than the baseline by 57 percent, 96 percent, and 63 percent, respectively.

Regulatory Concerns

Chemicals contained in the graphite technology are regulated by the Clean Water Act, the Safe Drinking Water Act, the Clean Air Act, the Superfund Amendments and Reauthorization Act, and the Emergency Planning and Community Right-to-Know Act. The technology does not generate wastes listed as hazardous (P or U waste) under RCRA, but some wastes may have RCRA hazardous characteristics.

Table 7.21 Summary of Human Health and Environmental Hazard Data and Risk Concerns for the Graphite Technology

Chemical ^a	Human Health Hazard and Occupational Risks ^b			Carcinogenicity Weight-of Evidence Classification	Aquatic Toxicity CC (mg/l)
	Inhalation ^c	Dermal			
	Toxicity ^d (mg/m ³)	Toxicity ^d (mg/kg-d)	Risk Concerns		
Alkyl Oxide	ND	NR ^e	no	Probable human carcinogen ^f	NR
Ammonia	0.1 (RfC)	ND	NE	none	0.0042
Copper Sulfate; or Cupric Sulfate	ND	ND	NE	none	0.00002
Cyclic Ether	ND	NR ^e	no	Possible/ probable human carcinogen ^f	NR
Ethanolamine	12.7 (LOAEL)	320 (NOAEL)	no	none	0.075
Graphite	56 (LOAEL)	ND	NE	none	ND ^g
Peroxymonosulfuric Acid	ND	ND ^h	NE	none	0.030 ⁱ
Potassium Carbonate	ND	ND ^h	NE	none	>3.0
Sodium Persulfate	ND	ND	NE	none	0.065
Sulfuric Acid	0.066 (NOAEL)	ND	NE ^j	none	2.0

^a Chemicals in bold were in both graphite technologies evaluated.

^b Risk evaluated for conveyorized process only. Risk concerns are for line operator (the most exposed individual).

^c Exposure and risk not calculated. Inhalation exposure and risk from fully enclosed, conveyorized process is assumed to be negligible.

^d Toxicity measure is RfC, RfD, NOAEL, or LOAEL, as indicated.

^e Toxicity data are available but not reported in order to protect proprietary chemical identities.

^f Specific EPA and/or IARC groups not reported in order to protect proprietary chemical identities.

^g Not expected to be toxic at saturation levels (based on EPA Structure-Activity Team evaluation).

^h Chemical has very low skin absorption (based on EPA's Structure-Activity Team evaluation); risk from dermal exposure not expected to be of concern.

ⁱ Estimated by EPA's Structure-Activity Team.

^j Chronic toxicity data are not typically developed for strong acids.

ND: No Data. No toxicity measure available for this pathway.

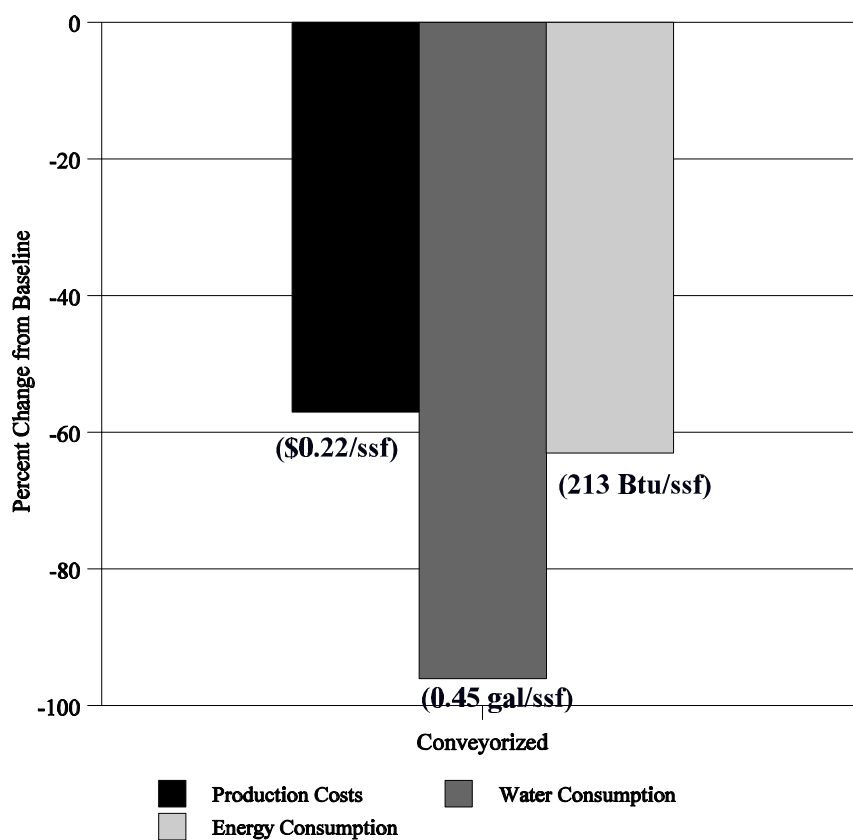
NE: Not Evaluated; due to lack of toxicity measure.

NR: Not Reported.

Social Benefits and Costs

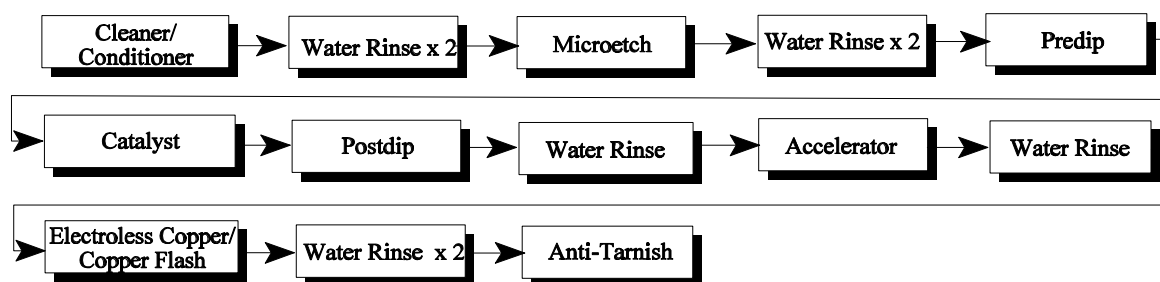
A qualitative assessment of the private and external benefits and costs of this technology suggests there would be net benefits to society if PWB manufacturers switched to the carbon technology from the baseline. Among other factors, this is due to lower occupational risks to workers and to reduced consumption of limited resources (water and energy).

Figure 7.4 Production Costs and Resource Consumption of Graphite Technology
(Percent Change from Baseline with Actual Values in Parentheses)



7.3.5 Non-Formaldehyde Electroless Copper Technology

Generic Process Steps and Typical Bath Sequence



Equipment Configurations Evaluated: Non-conveyorized.

Risk Characterization

Table 7.22 summarizes human and environmental hazards and risk concerns for non-proprietary chemicals in the non-formaldehyde electroless copper technology. The risk characterization identified occupational inhalation risk concerns for one chemical and dermal risk concerns for two chemicals. No public health risk concerns were identified for the pathways evaluated. However, proprietary chemicals are not included in this assessment and toxicity values were not available for some chemicals.

Table 7.22 Summary of Human Health and Environmental Hazard Data and Risk Concerns for the Non-Formaldehyde Electroless Copper Technology

Chemical ^a	Human Health Hazard and Occupational Risks ^b				Carcinogenicity Weight-of-Evidence Classification	Aquatic Toxicity CC (mg/l)
	Inhalation		Dermal			
	Toxicity ^c (mg/m ³)	Risk Concerns	Toxicity ^c (mg/kg-d)	Risk Concerns		
Copper Sulfate	ND	NE	ND	NE	none	0.00002
Hydrochloric Acid	0.007 (RfC)	NA	ND ^d	NE	IARC Group 3	0.1
Hydrogen Peroxide	79	no	630 (NOAEL)	no	IARC Group 3	1.2
Isopropyl Alcohol; or 2-Propanol	980 (NOAEL)	no	100 (NOAEL)	no	none	9.0
Potassium Hydroxide	7.1	no	ND	NE	none	0.08
Potassium Persulfate	ND	NE	ND	NE	none	0.92
Sodium Chlorite	ND	NA	10 (NOAEL)	yes	none	0.00016
Sodium Hydroxide	2 (LOAEL)	no	ND	ND	none	2.5
Stannous Chloride	ND	NA	0.62 (RfD)	yes	none	0.0009
Sulfuric Acid	0.066 (NOAEL)	yes	ND ^d	NE	none	2.0

^a Only one non-formaldehyde electroless copper technology was evaluated. All chemicals listed were present in that product line.

^b Risk evaluated for non-conveyorized process only. Inhalation risk from fully enclosed, conveyorized process is assumed to be low. Risk concerns are for line operator (the most exposed individual).

^c Toxicity measure is RfC, RfD, NOAEL, or LOAEL, as indicated. If not indicated, the type of toxicity measure was not specified in the available information, but assumed to be a LOAEL in risk calculations.

^d Chronic toxicity data are not typically available for strong acids.

ND: No Data. No toxicity measure developed for this pathway.

NE: Not Evaluated; due to lack of toxicity measure.

NA: Not Applicable. Inhalation exposure level was not calculated because the chemical is not volatile (vapor pressure below 1×10^{-3} torr) and is not used in any air-sparged bath.

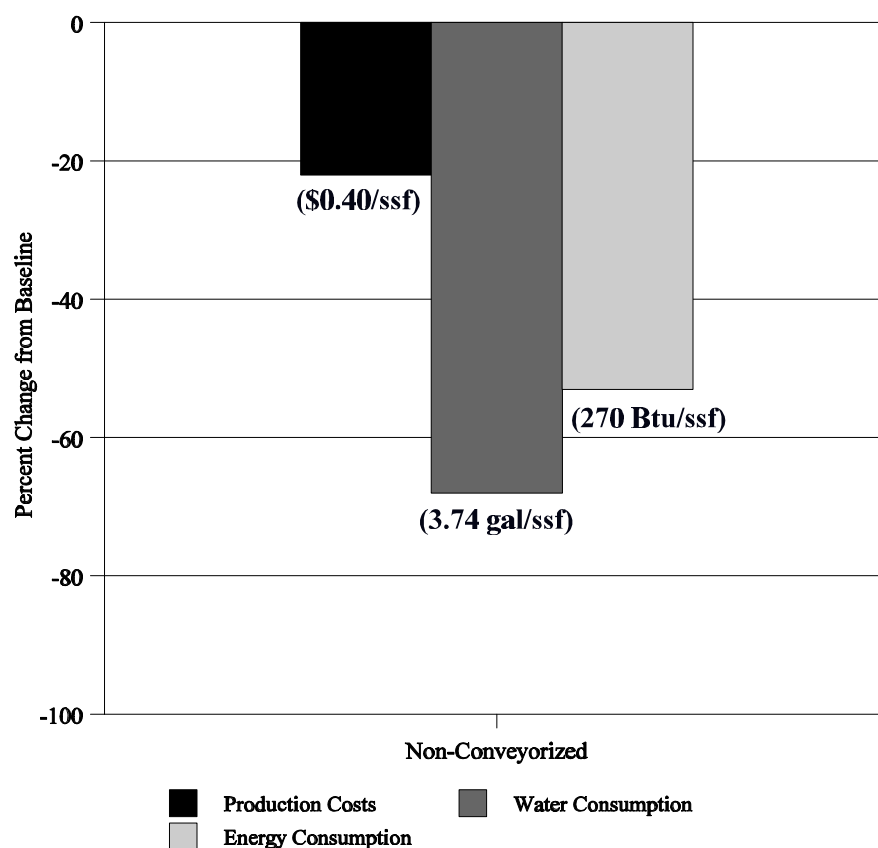
Performance

The performance of the non-formaldehyde electroless copper technology was demonstrated at two test facilities. The Performance Demonstration determined that this technology has the capability of achieving comparable levels of performance to electroless copper.

Production Costs and Resource Consumption

Computer simulation was used to model key operating parameters, including the time required to process a job consisting of 350,000 ssf and the amount of resources (water and energy) consumed. This information was used with a hybrid cost model of traditional costs (i.e., capital costs, etc.) and activity-based costs to determine average manufacturing costs per ssf and water and energy consumption per ssf. The non-conveyorized non-formaldehyde electroless copper process consumed less water and energy and was more cost-effective than the baseline process (non-conveyorized electroless copper). Figure 7.5 lists the results of these analyses and illustrates the percent changes in costs and resource consumption from the baseline. Manufacturing costs, water consumption, and energy consumption are less than the baseline by 22 percent, 68 percent, and 53 percent, respectively.

Figure 7.5 Production Costs and Resource Consumption of Non-Formaldehyde Electroless Copper Technology
(Percent Change from Baseline with Actual Values in Parentheses)



Regulatory Concerns

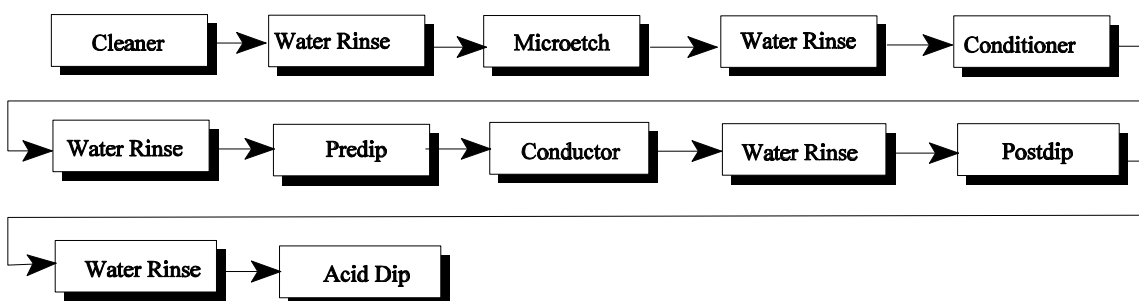
Chemicals contained in the non-formaldehyde electroless copper technology are regulated by the Clean Water Act, the Safe Drinking Water Act, the Clean air Act, the Superfund Amendments and Reauthorization Act, the Emergency Planning and Community Right-to-Know Act, and the Toxic Substances Control Act. The technology does not generate wastes listed as hazardous (P or U waste) under RCRA, but some wastes may have RCRA hazardous characteristics.

Social Benefits and Costs

A qualitative assessment of the private and external benefits and costs of this technology suggests there would be net benefits to society if PWB manufacturers switched to the non-formaldehyde electroless copper technology from the baseline. Among other factors, this is due to lower occupational risks to workers and to reduced consumption of limited resources (water and energy).

7.3.6 Organic-Palladium Technology

Generic Process Steps and Typical Bath Sequence



Equipment Configurations Evaluated: Non-conveyorized and conveyorized.

Risk Characterization

Table 7.23 summarizes human and environmental hazards and risk concerns for non-proprietary chemicals in the organic-palladium technology. The risk characterization identified occupational dermal risk concerns for one chemical, palladium salt. No occupational inhalation risk concerns were identified. The risk characterization identified public health risk concerns for the pathways evaluated. However, proprietary chemicals are not included in this table and toxicity data were not available for some chemicals.

Table 7.23 Summary of Human Health and Environmental Hazard Data and Risk Concerns for the Organic-Palladium Technology

Chemical ^a	Human Health Hazard and Occupational Risks ^b				Carcinogenicity Weight-of-Evidence Classification	Aquatic Toxicity CC (mg/l)
	Inhalation ^c		Dermal ^d			
	Toxicity ^e (mg/m ³)	Risk Concerns	Toxicity ^e (mg/kg-d)	Risk Concerns		
Hydrochloric Acid	0.007 (RfC)	NA	ND ^f	NE	IARC Group 3	0.1
Palladium Salt	ND	NA	NR ^g	yes	none	NR
Sodium Bisulfate	ND	NA	ND ^h	NE	none	0.058
Sodium Carbonate	10 (NOAEL)	NA	ND	NE	none	2.4
Sodium Bicarbonate	10 (NOAEL) ⁱ	NA	ND	NE	none	2.4 ⁱ
Sodium Hypophosphite	ND	NA	ND	NE	none	0.006
Sodium Persulfate	ND	NA	ND ^h	NE	none	0.065
Trisodium Citrate 5,5-Hydrate or Sodium Citrate	ND	NA	ND	NE	none	3.3

^a Only one organic-palladium technology was evaluated. All chemicals listed were present in that product line.

^b Risk concerns are for MHC line operators (the most exposed individual).

^c Inhalation risk concerns for non-conveyorized process only. Inhalation risk from fully enclosed, conveyorized process is assumed to be negligible.

^d Dermal risk concerns apply to both conveyorized and non-conveyorized equipment.

^e Toxicity measure is RfC, RfD, NOAEL, or LOAEL as indicated.

^f Chronic dermal toxicity data are not typically developed for strong acids.

^g Toxicity data are available but not reported in order to protect proprietary chemical identities.

^h Chemical has very low skin absorption (based on EPA's Structure-Activity Team evaluation); risk from dermal exposure not expected to be of concern.

ⁱ Chemical properties and toxicity measures for sodium carbonate used in exposure assessment and risk characterization since these compounds form the same ions in water and are used in aqueous baths.

ND: No Data. No toxicity measure available for this pathway.

NE: Not Evaluated; due to lack of toxicity measure.

NA: Not Applicable. Inhalation exposure level was not calculated because the chemical is not volatile (vapor pressure below 1×10^{-3} torr) and is not used in any air-sparged bath.

NR: Not Reported.

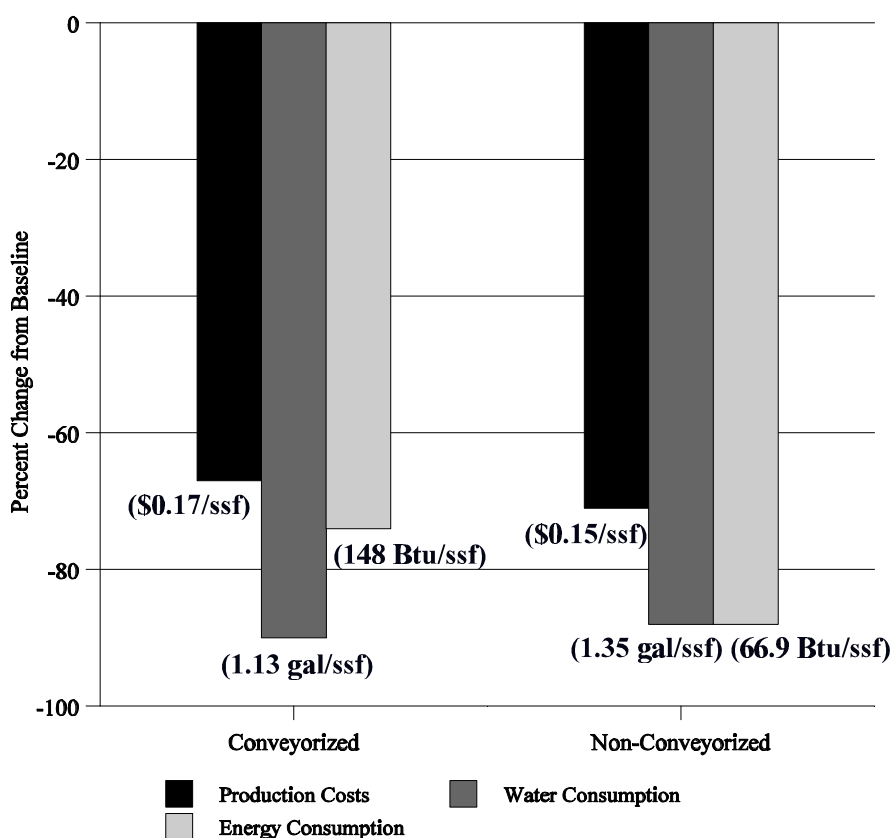
Performance

For the purposes of the Performance Demonstration project, the organic-palladium and tin-palladium technologies were grouped together into a single palladium technology category. The performance of the palladium technology was demonstrated at ten test facilities. The Performance Demonstration determined that this technology has the capability of achieving comparable levels of performance to electroless copper.

Production Costs and Resource Consumption

Computer simulation was used to model key operating parameters, including the time required to process a job consisting of 350,000 ssf and the amount of resources (water and energy) consumed. This information was used with a hybrid cost model of traditional cost (i.e., capital costs, etc.) and activity-based costs to determine average manufacturing costs per ssf and water and energy consumption per ssf. With either equipment configuration, the organic-palladium technology consumed less water and energy and was more cost-effective than the baseline process (non-conveyorized electroless copper). In addition, the conveyorized organic-palladium process consumed less water than the non-conveyorized process (\$1.13 gal/ssf vs. \$1.35 gal/ssf, respectively), but consumed more energy (148 Btu/ssf vs. 66.9 Btu/ssf). However, the conveyorized organic-palladium is not as cost effective as the non-conveyorized process (\$0.17/ssf vs. \$0.15/ssf, respectively). Figure 7.6 lists the results of these analyses and illustrates the percent changes in costs and resource consumption for either equipment configuration from the baseline.

Figure 7.6 Production Costs and Resource Consumption of Organic-Palladium Technology
(Percent Change from Baseline with Actual Values in Parentheses)



Regulatory Concerns

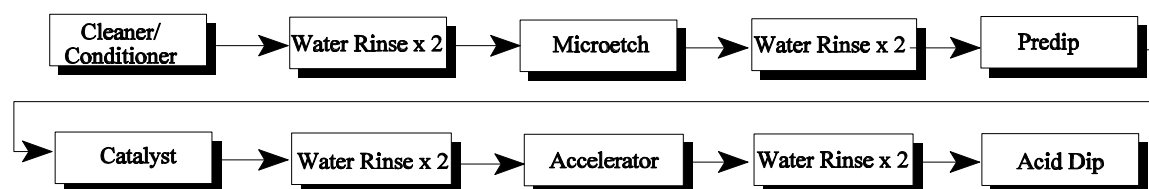
Chemicals contained in the organic-palladium technology are regulated by the Clean Water Act, the Clean Air Act, and the Emergency Planning and Community Right-to-Know Act. The technology does not generate wastes listed as hazardous (P or U waste) under RCRA, but some wastes may have RCRA hazardous characteristics.

Social Benefits and Costs

A qualitative assessment of the private and external (e.g., social) benefits and costs of this technology suggests there would be net benefits to society if PWB manufacturers switched to the organic-palladium technology from the baseline. Among other factors, this is due to lower occupational risks to workers and to reduced consumption of limited resources (water and energy).

7.3.7 Tin-Palladium Technology

Generic Process Steps and Typical Bath Sequence



Equip

ment Configurations Evaluated: Non-conveyorized and conveyorized.

Risk Characterization

Table 7.24 summarizes human and environmental hazards and risk concerns for non-proprietary chemicals in the tin-palladium technology. The risk characterization identified occupational inhalation risk concerns for two chemicals and dermal risk concerns for five chemicals. No public health risk concerns were identified for the pathways evaluated. However, five proprietary chemicals are not included in this table and toxicity values were not available for some chemicals. At least two of these chemicals (potassium carbonate and sodium bisulfate) have very low skin absorption, indicating risk from dermal exposure is not expected to be of concern.

Performance

For the purposes of the Performance Demonstration project, the organic-palladium and tin-palladium technologies were grouped together into a single palladium technology category. The performance of the palladium technology was demonstrated at ten test facilities. The Performance Demonstration determined that this technology has the capability of achieving comparable levels of performance to electroless copper.

Table 7.24 Summary of Human Health and Environmental Hazard Data and Risk Concerns for the Tin-Palladium Technology

Chemical ^a	Human Health Hazard and Occupational Risks ^b				Carcinogenicity Weight-of Evidence Classification	Aquatic Toxicity CC (mg/l)
	Inhalation ^c		Dermal ^d			
	Toxicity ^e (mg/m ³)	Risk Concerns	Toxicity ^e (mg/kg-d)	Risk Concerns		
1,3-Benzenediol	ND	NA	100 (NOAEL)	no	IARC Group 3	0.0025
Copper (I) Chloride^f	0.6 (LOAEL)	no	0.07 (LOAEL)	yes	EPA Class D	0.0004
Copper Sulfate^f	ND	NE	ND	NE	none	0.00002
Dimethylaminoborane	ND	NA	ND	NE	none	0.007 ^g
Ethanolamine	12.7 (LOAEL)	yes	320 (NOAEL)	no	none	0.075
Fluoroboric Acid	ND	NE	0.77	yes	none	0.125
Hydrochloric Acid^h	0.007 (RfC)	NA	ND	NE ⁱ	IARC Group 3	0.1
Hydrogen Peroxide	79	no	630 (NOAEL)	no	IARC Group 3	1.2
Isopropyl Alcohol; or 2-Propanol	980 (NOAEL)	no	100 (NOAEL)	no	none	9.0
Lithium Hydroxide	ND	NA	ND	NE	none	ND
Palladium^j	ND	NA	0.95 (LOAEL)	yes	none	0.00014
Palladium Chloride^j	ND	NA	0.95 (LOAEL)	yes	none	0.00014
Phosphoric Acid	ND	NE	ND	ND	none	0.138
Potassium Carbonate	ND	NA	ND ^k	NE ^l	none	>3.0
Sodium Bisulfate	ND	NA	ND ^k	NE	none	0.058
Sodium Chloride	ND	NA	ND	NE ^l	none	2.8
Sodium Hydroxide	2 (LOAEL)	NA	ND	NE	none	2.5
Sodium Persulfate	ND	NE	ND	NE ^l	none	0.065
Stannous Chloride^m	ND	NA	0.62 (RfD)	yes	none	0.0009
Sulfuric Acid^h	0.066 (NOAEL)	yes	ND	NE ^l	none	2.0
Triethanolamine	ND	NA	32 (LOAEL)	no	none	0.18
Vanillin	ND	NE	64 (LOAEL)	no	none	0.057

^a Chemicals in bold were in all tin-palladium technologies evaluated, unless otherwise noted.

^b Risk concerns are for MHC line operators (the most exposed individual).

^c Inhalation risk concerns for non-conveyorized process only. Inhalation risk from fully enclosed, conveyorized process is assumed to be negligible.

^d Dermal risk concerns apply to both conveyorized and non-conveyorized equipment.

^e Toxicity measure is RfC, RfD, NOAEL, or LOAEL as indicated. If not indicated, the type of toxicity measure was not specified in the available information, but assumed to be a LOAEL in risk calculations.

^f Either copper (I) chloride or copper sulfate was listed on the MSDSs for four of five tin-palladium lines evaluated.

^g Estimated by EPA's Structure-Activity Team.

^h Hydrochloric and sulfuric acid were listed on the MSDSs for four of five tin-palladium lines evaluated.

ⁱ Chronic dermal toxicity data are not typically developed for strong acids.

^j Palladium or palladium chloride was listed on the MSDSs for three of five tin-palladium lines evaluated. The MSDSs for the two other lines did not list a source of palladium.

^k Chemical has very low skin absorption (based on EPA's Structure-Activity Team evaluation); risk from dermal exposure not expected to be of concern.

¹ Dermal exposure level for line operator of conveyORIZED equipment was in top ten percent of dermal exposures for all MHC chemicals.

^m Stannous chloride was listed on the MSDSs for four of the five tin-palladium lines evaluated. The MSDSs for the remaining tin-palladium product line did not list a source of tin.

ND: No Data. No toxicity measure available for this pathway.

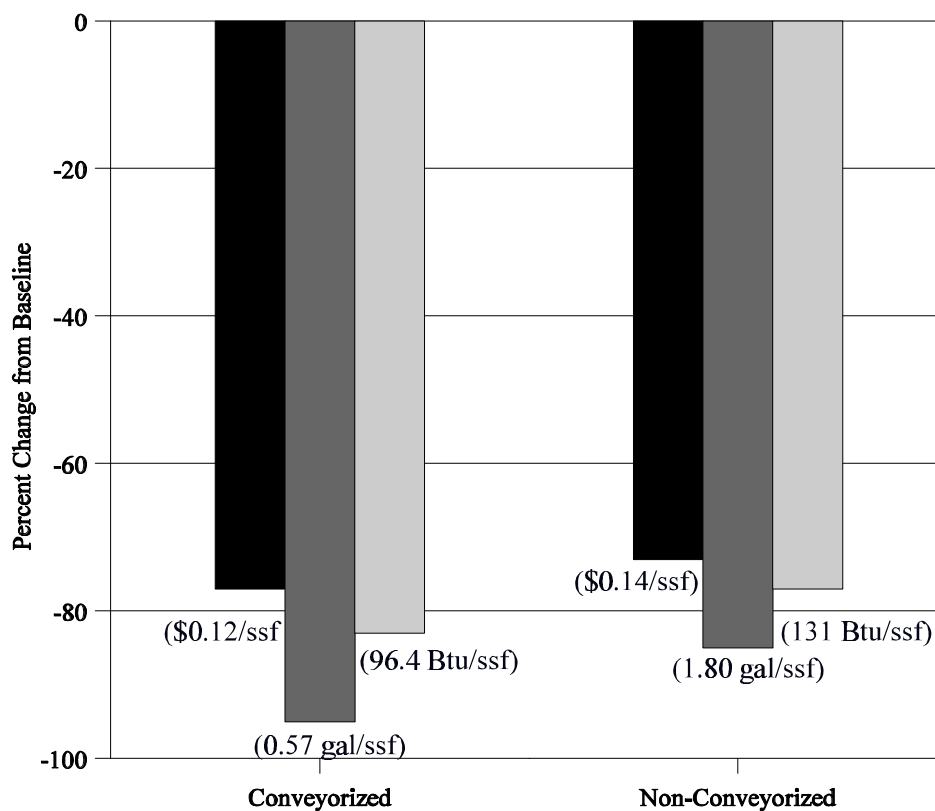
NE: Not Evaluated; due to lack of toxicity measure.

NA: Not Applicable. Inhalation exposure level was not calculated because the chemical is not volatile (vapor pressure below 1×10^{-3} torr) and is not used in any air-sparged bath.

Production Costs and Resource Consumption

Computer simulation was used to model key operating parameters, including the time required to process a job consisting of 350,000 ssf and the amount of resources (water and energy) consumed. This information was used with a hybrid cost model of traditional cost (i.e., capital costs, etc.) and activity-based costs to determine average manufacturing costs per ssf and water and energy consumption per ssf. With either equipment configuration, the tin-palladium technology consumed less water and energy and was more cost-effective than the baseline process (non-conveyORIZED electroless copper). In addition, the conveyORIZED tin-palladium process consumed less water and energy and was more cost-effective than the non-conveyORIZED process (\$0.12/ssf vs. \$0.14/ssf, respectively). Figure 7.7 lists the results of these analyses and illustrates the percent changes in costs and resource consumption for either equipment configuration from the baseline.

Figure 7.7 Production Costs and Resource Consumption of Tin-Palladium Technology
(Percent Change from Baseline with Actual Values in Parentheses)



Regulatory Concerns

Production Costs
 Water Consumption
 Energy Consumption

7.3 TECHNOLOGY SUMMARY PROFILES

Chemicals contained in the tin-palladium technology are regulated by the Clean Water Act, the Safe Drinking Water Act, the Clean Air Act, the Superfund Amendments and Reauthorization Act, the Emergency Planning and Community Right-to-Know Act, and the Toxic Substances Control Act. In addition, the technology generates a waste listed as hazardous (U waste) under RCRA.

Social Benefits and Costs

A qualitative assessment of the private and external (e.g., social) benefits and costs of this technology suggests there would be net benefits to society if PWB manufacturers switched to the tin-palladium technology from the baseline. However, this alternative contains chemicals of concern for occupational inhalation risk (for non-conveyorized equipment configurations) and occupational dermal contact risks (for either equipment configuration). Among other factors, net social benefits would be due primarily to lower production costs and to reduced consumption of limited resources (water and energy).

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